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While there are many techniques by which the temperature dependence of the magnetization can be probed, many suffer the disadvantage that not only the signal from the magnetic layer but also from the paramagnetic substrate are recorded. Here, optical techniques provide an essential complementary measurement with which only the surface of the sample is probed up to the skin depth(-200-300A). A sensitive temperature and wavelength dependent magneto-optic Keff Effect spectrometer was built using an intensity stabilized argon ion laser, a continuous flow cryostat and conventional optics necessary to probe the in-plane magneto-optic Keff effect signal.

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Final Report on the Progress of the Magnto-Optic Kerr Effect (KOKE) spectrometer

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The determination of the magnetization as a function of field and temperature is vital for the complete understanding of the magnetic properties of magnetic thin films and multilayers. Our particular interest in the temperature dependent magnetization are two fold: 1) Due to the reduction of the coordination number of the magnetic spins at surfaces and interfaces, stronger thermal fluctuations are expected to result in a stronger temperature dependence of the magnetization in magnetic thin films than in corresponding bulk materials [1]. 2) For a refined and precise evaluation of the temperature dependence of the interlayer coupling of magnetic/non-magnetic trilayer systems, using the ferromagnetic resonance (FMR) scheme presented in ref [2], the temperature dependence of the magnetization needs to be known.

While there are many techniques by which the temperature dependence of the magnetization can be probed, many suffer the disadvantage that not only the signal from the magnetic layer but also from the paramagnetic substrate are recorded. Here, optical techniques provide an essential complementary measurement with which only the surface of the sample is probed up to the skin depth (~200-300A). In many experiments the skin depth exceeds the film thickness of the magnetic thin films and multilayers investigated. Additional buffer layers between substrate and magnetic layer will then allow to completely avoid any unwanted signal from the substrate.

For the purpose of our studies, a sensitive temperature and wavelength dependent magneto-optic Kerr effect spectrometer was built using an intensity stabilized argon ion laser, a continuous flow cryostat and conventional optics necessary to probe the in-plane magneto-optic Kerr effect signal. The various components purchased to assemble the equipment as well as the parts build in OSU mechanical and electronics shops are listed below.

The special requirements for the operation of this temperature dependent Kerr effect spectrometer are:

i) The signal should be directly proportional to the magnetization. It should be furthermore independent of the background signal and in particular independent of drifts of the background signal. This is achieved by first inserting a feedback system, which allows to record the Kerr rotation angle rather than the backreflected intensity and secondly by inserting a calibration system. The calibration system allows immediate and fast (30sec) calibration of the measured Kerr rotation angle against the feedback voltage to adjust for drifts in the background intensity as well as to provide a calibration of the system to different wavelengths. Both, the feedback system as well as the calibration system make use of a Faraday rod with a large Faraday rotation, which is controlled in the first case by a DC as well as an AC magnetic field and in the second case only by a DC magnetic field. The corresponding control electronics was build at the OSU electronics shop.

ii) Due to the low film thickness the Kerr rotation angle is small and thus the signal to noise ratio is low. In order to achieve a higher signal to noise ratio and to avoid problems due to drifts of the signal, the acquisition time should be kept as short as possible. This is achieved by using an analogue to digital converter card (ADC) with which the feedback voltage signal is acquired directly through a computer rather than via a voltmeter. The time for a single loop is 45 sec and includes an average over 50samples per point.

The achievements at room temperature with the described setup are 1 mdeg resolution as tested on thin Co/Ru/Co trilayer films with a total film thickness of 70A and a total Kerr rotation of 20 mdeg. These tests will be extended in the future to samples with lower Kerr rotation. In order to keep this performance to low temperatures the mechanical stability of the cryostat mounting was considerably improved. The cooling process induces unavoidable thermal stress and/or tension in the sample holder and causes slight motions of the sample as well as the laser position. This improvement of the mechanical stability contributed the most crucial and most time consuming part of the experimental setup.

The motion between sample and laser beam during the cooling process puts a strict requirement on the sample surface which has to be as flat as possible. The tested Co/Ru/Co trilayer systems grown on mica substrates did not provide flat enough sample surfaces for such sensitive measurements and

currently a new series of samples is in preparation. These include single layer Co and Fe films with varying film thickness as well as Co/Cu/Co and Co/Mn/Co trilayer systems. The latter system is of particular interest as recent experiments have shown a strong interdependence between the magnetism of the spacer layer and the interlayer (indirect) exchange coupling. The interesting feature is the strong decrease with temperature of the antiferromagnetic exchange coupling between adjacent cobalt layers, which vanishes at about the Neel temperature of the Mn interlayer. In order to have access to more information concerning the Mn magnetic ordering, it is vital to investigate the magnetization curves vs temperature. Those experiments would be very useful and would allow (i) to determine the interfacial coupling between the Mn and Co, (ii) to confirm he origin of the exchange coupling by correlating the dependence of the magnetic ordering of the Mn with temperature with the indirect exchange coupling. These temperature dependent magneto-optic effects will be complemented by ferromagnetic resonance experiments.

The equipment purchased for this project:

1) One 600 mW stabilized argon-ion laser from Spectra Physics BeamLok6000, stable to at least 0.1% thus not requiring an external stabilization system for the laser intensity

2) Two polarizing optics (Glan-Thomson type) from Melles Griot

3) One optical table plus support legs from Melles Griot

3) Three Faraday rotator rods (Schott glass SF6 selected for its large Faraday rotation, 20mm diameter, 60mm length) customer specified fabrication

4) One continuous flow cryostat from Janis with four optical windows, selected for its small cross section to fit into the magnet gap of the exisiting electro-magnet

5) Six additional optical windows SFL6 from Schott glass, selected for low Faraday rotation and replacing the optical windows provided in the Janis continuous flow cryostats

6) One analogue to digital card from National Instruments NI replacing the existing IEEE data acquisition system. This increases data acquistion by a factor of 10-15 faster and allows in addition an averaging of the signal over 50 times per point.

Home build instrumentation:

1) One controller for the Faraday rotator as part of the feedback system

2) One controller for the Faraday rotator as part of the calibration system

3) One cryostat mount and one beam steering mount to adjust the cryostat to the beam position and to steer the beam onto the sample with a finite angle of incidence (45°).

References:

[1] D. Mills, Phys. Rev. B (to be published)

[2] Z. Zhang, L. Zhou, P. E. Wigen and K Ounadjela, Phys. Rev. Letters, 73, 336 (1994)

[3] Y. Henry, K. Ounadjela, Phys. Rev. Lett. 76, 1996 (1994)